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REPLACEMENT OF FIRST FIRE COMPOSITION IN M127A1 GROUND ILLUMINATION SIGNAL

Russell N. Broad

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13. ABSTRACT (Maximum 200 words) A study was conducted to replace the first fire composition in the M127A1 ground illumination signal. The original first fire composition contained tetranitrocarbazole, a sole source material, and barium nitrate, a toxic material. Program costs were minimized by choosing a presently used first fire composition as a replacement. A data base of such compositions was created. It was used to pick candidate replacement compositions. The compositions were loaded into illuminant assemblies and tested statically. Results from this test showed that Starter Mix (SM) XXV was the best candidate composition. It was loaded into complete signals that underwent ballistic testing. Signals with SM-XXV met all applicable Military specification requirements. The success of the program justified the approach of choosing a currently used first fire composition.				
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CONTENTS

	Page
Introduction	1
Technical Approach	1
Result	2
Composition Data Base/Selection of Candidate Compositions	2
Static Tests of Candidate Compositions	2
Ballistic Testing for Prove Out of New First Fire Composition	3
Conclusions	3
Recommendations	4
References	17
Distribution List	19

TABLES

1	Formulations for pyrotechnic first fire compositions	5
2	Database for first fire and pyrotechnic compositions	6
3	Candidate first fire compositions	11
4	Static tunnel (ARDEC) data for various illuminant assemblies	12
5	Static tunnel (LHAAP) data for standard and candidate illuminant assemblies	13
6	Ballistic data for signals conditioned at -65°F	14
7	Ballistic data for signals conditioned at 70°F	15
8	Ballistic data for signals conditioned at 165°F	16

INTRODUCTION

The pyrotechnic first fire compositions covered by MIL-P-48240 are used on a wide range of colored signals and illuminating projectiles. There are three of these compositions, each formulated to give a distinctive color. Table 1 give the formulations for these compositions. TNC is a common constituent of these compositions. TNC was first synthesized in the late 1800s and found use in pyrotechnics in World War II (ref 1). Picatinny Arsenal investigated its use as a first fire constituent in the early 1950s (ref 2). It is considered an explosive material. Upon ignition it produces considerable energy and essentially gaseous products. These properties enable the first fire compositions to ignite illuminating and signal compositions. The first fire compositions are either pressed on top of, or brushed onto, the surfaces of illuminating and signal compositions pressed into canisters or sleeves. The first fire compositions are initiated by expelling charges or ignition compositions. Through the years, the first fire compositions have given reliable, consistent performance.

In the early 1990s, the availability of TNC became uncertain because its sole producer did not want to manufacture it anymore. Although another company picked up production, availability could not be guaranteed. TNC has no commercial market and the military market has declined dramatically. The resulting low demand make its production marginally profitable. Thus, there is little motivation to continue its production. This situation led to execution of an engineering study to eliminate use of TNC. A secondary purpose of the engineering study was the replacement of barium nitrate in the igniter compositions. This material is in two of the pyrotechnic first fire compositions. Like all water soluble barium salts, it has high acute toxicity. Further, disposal of waste containing it is relatively expensive because it cannot be landfilled. This report describes the results of the engineering study.

TECHNICAL APPROACH

One approach to remove TNC could have been reformulating the first fire compositions without it. This would have resulted in novel compositions. The approach taken, however, was replacement of the three first fire compositions with a pyrotechnic composition that was presently being used on other items. The advantages of this approach follow. First, it minimized testing required for qualification since a presently used composition had a history associated with it. This included functioning performance in various end items, environmental considerations, cost and data on storage stability, safety, thermodynamics, and kinetics. Second, manufacturing procedures and drawings already existed for the composition. Third, use of one first fire composition would simplify manufacturing since one batch of composition could be used for various items, regardless of the items' signal or illumination colors.

One possible drawback to this approach was the elimination of first fire compositions that were tailored to the illuminating or signal composition color. Several individuals knowledgeable in the field use the colored signals revealed that the color of the first fire flash was insignificant in affecting an observer's ability to distinguish illuminant or signal colors. The flash of the first fire is of very quick duration (<500 ms) compared to the burn time of the illuminants or signals (>25 sec). Thus, elimination of the color requirement for the first fire compositions was of no concern and this approach was pursued.

The program was conducted in three phases. First, other presently used pyrotechnic compositions were identified and pertinent data was collected on them. For maximum flexibility, we did not confine our search to only igniter and first fire compositions (henceforth we will use the term first fire to apply to igniter compositions as well). A data base was created from which the best candidate compositions were selected. Second, static functioning tests were performed on illuminant assemblies which contained the candidate first fire compositions and the standard first fire compositions. These tests determined if the candidate replacement compositions would have any adverse affect on the static requirements for the illuminating assemblies. Third, items were loaded with both the candidate replacement composition and the standard first fire composition, and underwent first article ballistic testing.

RESULT

Composition Data Base/Selection of Candidate Compositions

Identification of presently used first fire compositions was begun by generating a list of drawings that contained words igniter, ignition, and first fire in their titles. These drawings were then obtained. A second source for such compositions was reference 3. This procedure ensured that the vast majority of, if not all, presently used first fire compositions were identified. With this information, a minimal data base that included first fire formulations and common names was created. Further information was then added. This included impact, electrostatic and friction sensitivity data, hazard class, heat of reaction, autoignition temperature, burn rate, cost per pound, and qualitative ranking of toxicity. Not all of his data could be obtained for every composition. The data base is shown in table 2. The references for the various data are cited in the table.

Criteria were developed to select the most promising candidate replacement compositions. Criteria included toxicity, cost, sensitivity, availability of constituents, history of problems, and burning characteristics. It was decided to eliminate those that would be least likely selected. The first criterion for elimination was presence of acutely toxic or carcinogenic constituents. This included barium, lead salts, and chromates. This consideration eliminated many of the compositions shown in table 2 as candidates. The remaining compositions were eliminated because of safety or processing issues, autoignition temperatures exceeding 500°C (ref 4), or other considerations such as cost. Since the first fire compositions are in contact with the flash from expelling charges for short duration's, they must reach their autoignition temperatures quickly. This is more easily accomplished if the autoignition temperature is relatively low. The remaining compositions, which were chosen as candidates, were Starter Mix XXV, IM-6, and I-548 (no. 10, 34, and 40, respectively in table 2). Table 3 shows further detail on these compositions.

Static Tests of Candidate Compositions

Composition I-548 was dropped from consideration because the required grade of calcium resonate could not be obtained easily. Only starter Mix XXV and IM-6 were evaluated statically. Table 4 is a matrix of assembly types and quantities statically tested. Assemblies with the standard first fire compositions served as controls. The choice of assemblies was based upon the items planned for the qualification tests. In turn, the choice of items was based upon what items would be in production during the duration of the program.

The required parts for the assemblies were ordered and tooling was fabricated for loading the assemblies. The Pyro Systems Branch of the U.S. Army Armament Research, Development and Engineering Center (ARDEC), Picatinny Arsenal, New Jersey mixed all the pyrotechnic compositions and loaded all the assemblies used in the static tests. The Branch also conducted all the static tests in its own flare tunnel. Table 5 is a roll up of averaged static test parameters for the assembly/first fire combinations tested.

The efficiency data shows that SM-XXV offers significantly better performance over IM-6 for the M125A1 and M127A1, while the IM-6 is much better for the M158. They are nearly equal for the M583A1. SM-XXV was better than the standard first fire for all items except the M583A1. Here, the standard was approximately 13% higher. Based on this static data, as well as SM-XXV's lower cost, we decided to test SM-XXV in the ballistic testing.

Ballistic Testing for Prove Out of New First Fire Composition

In consultation with ARDEC's Product Assurance and Test Directorate, a test plan was drafted for ballistic testing. The ballistic test consisted of functioning tests at conditioning temperatures specified in the military specifications. Additionally, some illuminant assemblies from the lot used for the ballistic test were statically tested. Quantities were per first article requirements. This minimal amount of testing was justified since changing the first fire would in no way affect the hardware and other energetic material fills in the item.

The ballistic tests were conducted by Thiokol Corporation at Longhorn Army Ammunition Plant (LHAAP). During the time period in which static testing at ARDEC concluded and ballistic tests begun, numerous production lines were closed at LHAAP. Startup of these lines exclusively for this program would have been prohibitively expensive. Consequently, only the M127A1 signal experienced ballistic testing.

Thiokol loaded the items per the technical data package requirements and performed testing per the Scope of Work. Table 6 shows their static burn data. The candlepowers measured at LHAAP were higher than ours; this was due to differences in the tunnels and test procedures. As expected, the candlepower achieved with SM-XXV was higher than FF-I. Since exact illuminant weight data was unavailable, efficiencies are not reported. Table 7 presents the ballistic (flight) data. The data shows that aside from two failures at 70°F, all signals met the requirements. One failure was non-expulsion of the signal; the other, failure of the round to expel. Neither was related to first fire function. The only ballistic parameter that could have been possibly affected by the change in first fire was the burn time. The differences between the signals with FF-I and SM-XXV for this parameter were small and within the standard deviations at all temperatures.

CONCLUSIONS

The success of the project vindicated the selected approach. Choosing a presently used igniter composition kept the cost and technical risks of the program as low as expected. The need for extensive testing above first article requirements was eliminated.

RECOMMENDATIONS

Other items incorporating igniter compositions with sole source, toxic, or environmental/objectionable constituents should be evaluated for igniter replacement. Programs to achieve this objective would be of minimal scope since they would have the data base of igniters generated in this program as a starting point.

Table 1
Formulations for pyrotechnic first fire compositions

<u>Constituent</u>	<u>Requirements</u>	<u>Nominal weight percent</u>		
		<u>Type I</u>	<u>Type II</u>	<u>Type III</u>
Barium nitrate	MIL-B-162 Average particle size $\leq 20 \mu$	50	---	50
Strontium nitrate	MIL-S-20322 Grade A or B	---	50	--
Tetranitrocarbazole	MIL-T-13723	10	10	10
Silicon	MIL-S-230 Average particle size $\leq 10 \mu$	20	16	13
Zirconium hydride	Commercial	15	15	20
Polyvinyl chloride	MIL-P-20307	---	5	3
Laminac 4116 + 1% Lupersol DDM catalyst	Commercial	5	4	4
Color requirement		Yellow	Red	Green

Table 2
Database for first fire and pyrotechnic compositions

Table 2 Database for first fire and pyrotechnic compositions

No Fuel (Percent):	Oxidant (Percent):	Additive (Percent):	Binder (Percent):	Solvent (Percent):	Type of Comp.	Cost E.Sta.(J) Uncon/Con Steel/F PA ₁ (*) (BM)	Frict.P Steel/F PA ₁ (*)	Impact BR	Heat of Rec Cal/g Auto/DTA	Ig.Temp Degrees C	Compat Gn/Haz (DDD)	Toxicity
1 Lead Azide					Exp	0.007	Exp/Exp 4-5					
2 Nitrocellulose					Exp	0.049j	Burns/	3-5		160	0 /1.1	Not Toxic
3 PETN					Exp	.06 / .21	Cr./NR	6				/1.1
4 TNT					Exp	.06 / 4.4	NR/NR	14	1040	/0475		/1.1
5 RDX					Exp	>11.03	Exp/NR	8	1240	260 (5s)		/1.1
6 Black Powder					Exp	3.00 12.5/0.8	SnP/NR	16	684	288 (5s)		/1.1
7 98.5-99 RDX		(1.5 St.Acid			Exp.	11.025	Cr./NR	8-12		190		/1.1
8 30 Charcoal	70 KN03				St.MIX11	3.24 0.75 BM	NR/NR	310 NR	1.9s/mg	418		6 /1.3 MOD.
9 83.3 Dry Mix Dry Mix (#9): 26/4/13/51/C/Al Binder Solu(#9):			16.7 B.Solu		StartMix	2.35 1.25	NR/NR	15 BOE	0.3s/mg	401		6 /1.3 MOD
10 26/13/4/51/Al/C	35/22/KN03/Fe203		6 NC	94Acetone	St.MIX11	0.59	NR/NR	15 BOE	5.0s/in	1186		421
11 60 Dry Mix Dry Mix (#11): 16.8/10/5/C/Starch Binder Solu(#11):	43.2/30/KC103/NaHCO3		4 NC	94Acetone	St.MIX11	2.71	NR/NR	28 BM	>1 s/mg	182		6 /1.1 SLIGHT
12 35 pts Sb	35/30pts;CaS12/KC104		64pts(B NC	92 Ace.)	FFP-555		NR/NR	15 BOE	13s/in	1812		446
13 40 Al	30/30;Ba(NO3)2/KC104				Flash	NR 3.25	Cr/	22 ERL				
14 23/15; Al / S	42 Ba(NO3)2				Flash	3.09 0.225	NR/NR	14	0.2s/mg	344		0 /1.1 MOD.
15 91 Bk.Powder	9 Al				FFP-1	7.53 3.2/0.73	SnP/NR	27 -36		762		0 /1.1 TOX
16 34/26; Mg/Al	40 KC104				FF	22.4 0.0125	CO/CD	6		380		A /1.1 TOXIC
17 25.5/12.8; Mg/Al	25.5/28.1;BaCrO4/KC1		8.1Viton A	B.Acetate	FF,Flare	8.89 0.051	CB/CB	12		550		6 /1.3 MOD
18 50/50; FF/Flare	90 BaCrO4				FF,Flare	10.1 0.0034	CB/CB	16	0.6s/in	480		6 /1.3 MOD
19 Dry Mix (#16): 25/25; Ti/Si Binder Solu:	28 Teflon		7 Hycar	MEK or Acetone	FF,VII	7.60	NR/NR		3.0s/in	360		6 /1.3 MOD
20 30 W	25/25; Fe304/Pb304		(10.9 NC	89.1 Ace- tone)		1.31	NR/NR	15 BOE	3.0s/in	360		762
21 25/25; Si/Ti	55/10;BaCrO4/KC104	5 D.earth	Viton A		FFMIX		NR/NR			391		/1.3
22 10 B	50 Pb304	(Graphite	NC	Acetone)	FF,MIXX	1.29 1.625	NR/NR	NR 215	0.3s/mg	275		6 /1.1 MOD
	90 Pb02			E.Acetate	FF,PComp	7.90 0.0125	CB/CB	2		327		A /1.1 MOD

Table 2
(cont)

Table 2 Database for first fire and pyrotechnic compositions

No Fuel	Oxidant	Additive	Blinder	Solvent	Type	Cost	E.Sta.(J)	Fr/c.P	Impact	BR	Heat	Ig.Temp	Compat	Toxicity
(Percent):	(Percent):	(Percent):	(Percent):	(Percent):	of Comp. (Percent)	\$/Lb	Uncon/Con (BH)	Steel/F	PA ₁ (*)	*As Shown	of Rec Cal/g Auto/DTA	Degrees C	Gr/Haz	*****Ref
23 33 Bk Powder Red Pyro Comp. 1 2/17; Mg, Gran 4	67 Red Pyro. Comp. 13/21.4 NaNO ₃ /KClO ₄ 7.5 Glisonite 2.8 Graphite				FF4M131S								D /1.1 MOD	CAR.SUS
24 30 Ti	70 Fe2O3				FF30M1XU	1.09	N/R	Cr/NR	10 BOE	6.5s/in	659	659	G /1.3 SLIGHT	
25 FF: I, II & III, TNC Pyro. Comp. 1					FF: I, II, III	9.76	9.76	Cr-a/NR	26		680	476	D /1.1 MOD	
1:20/15; Si/ZrH2 1:116/15; Si/ZrH2 1:1130/20; Si/ZrH2	50 Ba(NO3)2 50 Sr(NO3)2 50 Ba(NO3)2	10TNC 10TNC; 5PvCl 10TNC; 3PvCl	5 Lam. 4116 4 Lam. 4116 4 Lam. 4116		FF: I, II, III	3.78 3.67 3.64				8.6s/in 12 s/in 12 s/in			CAR.SUS TOXIC CAR.SUS	
26 TNC, FF: I (Slurry)		Pluronic F68	Cel. Nitrate		FFM125A1									
27 TNC, FF: I (Slurry)		Pluronic F68	Cel. Nitrate		FF127A1									
28 TNC, FF: I (Slurry) or 16 B Powder, Cl-8	84 TNC FF: I (Slurry)	Pluronic F68 Pluronic F68	Cel. Nitrate Cel. Nitrate		FF158A1 FFM158A1									
29 TNC, FF: I (Not A Slurry) or 19 B powder Ig. Pwd.: 19 B 18/58; Ty IV Tef/KH03	3g Ignition Pwd. (Not A Slurry) 18/58; Ty IV Tef/KH03		5 P. ester 1.8 (10 NC		FFM583A1 FFM583A1	3.78 14.2								
30 20 Si	80 Pb304		1.8 (10 NC	90 Acc.)	FFM201A1	0.82		NR/NR	>15BOE	4.4s/in	335	371	/1.3 TOXIC	
31 10 Si	90 Pb304		1.8 (10 NC	90 Acc.)	FFM1X	0.65		NR/NR		1.5s/in	256		/1.3 TOXIC	
32 25 B VAAAR is no longer being produced. An old quotation	75 KN03		1 UAAAR	2 \$19.00 / lb. was used for cost	I-SpMix	19.3	0.124	CB/NR	10	2.3s/in	1594	414/431.2	/1.1 MOD.	
33 50 Si	20/30; Pb02/Cu0			Igniter	Igniter	1.67			15		380	476		TOXIC
34 40 Si	54 KN03		6 Viton A	IM-6	IM-6	3.82	>1	>2477 ft. lbs	>49.6	11.6in/	673.5		G MOD	
35 65 Zr	25 Fe2O3	10 D.Earth	UAAAR added	I-AIA	I-AIA	>69	0.0024	CB/NR	24		0.6s/mg	550	G/1.3 SLIGHT	
36 21 Zr	79 BaCr04			DP-162	DP-162	25.6	0.0013	PB/NR	23		1.0s/in	326	/1.1 CAR.SUS	
37 19 B	58/18; KN03/TFE		5 Lam4116	SI-282	SI-282		0.283	Spk/NR	9			NR(5sec)	D/1.1 MOD.	
38 23.1 B	70.7 KN03	0.5 Pluronic F68	5.7 Lam4116	Igniter	Igniter		1.0BM	NR	13		1600	400/565	D /1.1 MOD	
39 16.5 Mg	80.5 Ba02	2/1; CaRes/Gr- phite		I-527	I-527	1.95	1.25	Spa/NR	23			375	G /1.3 CAR.SUS	
40 15.0 Ty-III Mg(Gran	65.0 Sr02	7/13; TyI/TyII Ca Resinate		I-548	I-548		0.05 BM	Spk/NR	8			239		MOD
41 6 Mg (Gr.12) 1-136; 10 Ca Res. 90 Sr02	94 I-136			I-194 I-136	I-194 I-136	5.97 0.05	0.25 0.05	Spa/NR Spa/NR	35ERL 16		.5s/mg	287 280	G /1.1 SLIGHT G/1.1 SLIGHT	

Table 2
(cont)

Table 2 Database for first fire and pyrotechnic compositions

No Fuel (Percent):	Oxidant (Percent):	Additive (Percent):	Blinder (Percent):	Solvent (Percent):	Type of Comp.	Cost \$/Lb	E.Sta.(J) Uncon/Con (Bk)	E.P Steel/F PA ₁ (%)	Impact BR	Heat of Rec Cal/o	Ig.Temp Degrees C Auto/DTA	Compat Gr/Haz (DDO)	Toxicity *****Ref
42 5 B	95 BaCrO4				DP-T-10	7.15		CB/NR	>40	1.9s/in	265	553/675	/1.1 CAR.SUS
43 10 B	90 BaCrO4				DP-479	10.1	0.02	CB/CB	12	0.7s/in	480	615/705	/1.1 CAR.SUS
44 10 B	90 BaCrO4		1 VAAR (See record #32)		JP-879	9.70	0.25	CB/NR	24	1.5s/in	463	560	/1.1 CAR.SUS
45 15 B	85 BaCrO4				DP-523	13.2		CB/NR	26	1.5s/in	502	/645	/1.1 CAR.SUS
46 19 B	81 BaCrO4				DP-T-10	15.7	0.50	CB/NR	10	2.0s/in	276	656	/1.1 CAR.SUS
47 15 B	44/41; BaCrO4/Cr2O3				DelayMix	13.9				4.5s/in			CAR.SUS
48 14 B	44/42; BaCrO2/Cr2O3				DelayMix	13.2				6.5s/in			CAR.SUS
49 13 B	41/44; BaCrO2/Cr2O3				DelayMix	12.5				8.5s/in			CAR.SUS
50 50 W	40/10; BaCrO4/KClO4				DelayMix	7.27		NR/NR	22 BOE	12s/in	233	270	/1.3 CAR.SUS
51 20 W	70/10; BaCrO4/KClO4				DelayMix	5.68				41s/in			CAR.SUS
52 9 70/30ZnNi alloy 217 30/70ZnNi alloy	60/14; BaCrO4/KClO4				DP-1415, Tyll	17.9		CB/NR	>40	6.0s/in	521	325	/1.3 CAR.CUS TOXIC
53 3 70/30 ZnNi alloy 623 30/70ZnNi alloy	60/14; BaCrO4/KClO4				DP-1415, Tyll	16.6		CB/	>40	11s/in	521	325	/1.3 CAR.SUS TOXIC
54 55 Mn	45 PbCrO4				DP-D16	1.07				2.2s/in	230		CAR.SUS
55 33 Mn	30/37; BaCrO4/PbCrO4				DP-D16B	1.99		NR/NR	15 BOE	8.4s/in	256	460	CAR.SUS
56 32.8 Mn	37/30.2; BaCrO4/PbCrO4				DP-D16C			NR/NR	15 BOE	13s/in	262		/1.3 CAR.SUS
57 28 Zr	72 PbO2				DelayMix	22.5				4.5s/in			Toxic
58 5/31; Zr/Ni	42/22; BaCrO4/KClO4				DP-T-2	10.5				6.5s/in			CAR.SUS
59 5/17; Zr/Ni	70/8; BaCrO4/KClO4				DP-HP-25	9.71				18 s/in			CAR.SUS
60 32-58 W	32-56 BaCrO4 & 10-14 KClO4		VAAR (See record #32)		Delay P.	7.04	11.03	NR/	36		270		MOD
61 53 Zr	21/26; KClO4/MoO3				SI-98								
62 48.7 Zr	31.3/20; MoO3/Cr2O3				SI-113	54.1	0.00018	CB/CB	34	0.8s/in	605	400	G/1.3 Low
63 40 Zn; 20 Al	20 KClO4; 20 KN03				PFP-600	3.82	>50		14		700		G /1.3 MOD
64 60-67 Al	33-40 KClO4				PFP-600	5.9	0.37	CB/NR	24		2284		D /1.1
65 22.5/10; Al(F1.)/S	64/3.5; KClO4/SbS2				M-80								

Table 2 Database for first fire and pyrotechnic compositions

No	Fuel (Percent)	Oxidant (Percent)	Additive (Percent)	Binder (Percent)	Solvent Type (Percent)	Type of Comp.	Cost E.Sta.(J) \$/LB Uncon/Con Steel/F (BK)	E.Fric.P PA,(%)	Impact BR WAS Shown	Heat of Rec Cal/g Auto/Ota	Ig.Temp Degrees C	Compat Gr/Haz (DDP)	Toxicity *****Ret
66	40.0 Zr	60 BaCrO4				Propel't	11.03	NR/NR	4 -6			C /1.1	
67	M1 Propellant					Propel't	5.2	Snp/NR	2 -3			C /1.1	
68	M9 Propellant					Propel't	>12.5	NR/NR	4			C /1.1	
69	M30 Propellant					111,RT	>50	Cr-a/NR	19		344	D /1.1 High	
70	42 30/50 Mg	44 Sr(NO3)2	7 Declarane	7 VAAR (See record #32)		FY-1450	11.82	NR/NR	21		/518	D /1.1 MOD	
71	48-65 20/50 Mg	31-47.5 NaN03		4-4.5 VAAR (See record #32)									
72	75 30/50 Mg	10 Teflon		15 Viton A		111,F,IR	9.00	NR/NR	18		400	A /1.3 SL-MOD.	
73	50 30/50 Mg	38 NaN03		5 Lamd116		FY-1444	4.28	NR/NR	19		1456	/1.1 SL-MOD	
74	45.9 30/50 Mg	34 NaN03		9 Lamd116		FY-1192					610		
75	46% 20/50 Mg	45 NaN03		Acetone		FY-1451					431		
76	65 Mg	28 TFE		7 Hycar		MEK or Ac 111,F,IR	7.60	NR/NR	16		400	G /1.3 SL-MOD	
77	Opt. Fuel: 38 Mg 30/50 of: a.Ty-I(Sp.14067)or b.Ty-II(I(Sp.382C)or c.Ty-IV,I(EI,Sp.14067	46 Ba(N03)2, Cl-2 (30um)	16 PuCl	5 Lamd116		111,M125	11.02						
78	Opt. Composition: 66 Mg30/50TyI(14067 or 65 Mg30/50TyI(14067	29 NaN03 31 NaN03		5 Lamd116 4 VAAR		111,M127 111,M127	11.02 11.02						
79	33 Mg30/50TyI 14067	48 Sr(N03)2,GrB	15 PuCl	4 VAAR		111,M158	11.02						
80	28 Mg30/50TyI 14067 & 20 Mg50/100EI 14067	41 NaN03,GrB,CI-2		11Lamd116		111,.593	11.02						

DATA COLLECTION

The thermal and sensitivity data were collected from ICDSB statements, from a DTIC Technical Report, NAD-E600-496, entitled, "Compilation of Magic and Test Data for Parathetic Compensations by Fred L. McIntire, and from two laboratory reports: one entitled "Development of Ionitic Parathetic Compensations for High Altitude Emulation of Illuminance" by R. L. McIntire, and another entitled "Development of Parathetic Compensations for High Altitude Emulation of Illuminance" by R. L. McIntire, and a second entitled "Development of Parathetic Compensation and Evaluation of Ionitic Temperature Compensation and Differential Thermal Compensation for Parathetic Emulation of Illuminance" by R. L. McIntire and J. C. Crane.

In order to expedite the collection of burning rate data, two sources were used that presented the data in two different units. Some of these rates were calculated from HCS09 test statements which presented burning times for 20 mg of loose composition. The remainder of these rates were calculated from test statements which presented burning times for 100 mg of loose composition. The remainder of these rates were calculated from test statements which presented burning times for 100 mg of loose composition. The remainder of these rates were calculated from test statements which presented burning times for 100 mg of loose composition.

The toxicity and compatibility data were collected from ICSD9 statements and from a Noyes Publications Handbook of Toxic and Hazardous Chemicals, 1991.

Cost data was collected from the latest editions of the Monthly Chemical Marketing Reporter, published by the Schnet Publishing Company of New York and by direct contact with users and manufacturing companies.

Finally, a few propellants and explosives were used for users and manufacturing companies.

Table 2
(cont)

Abbreviations

E. Sta.	= Electrostatic	Pyro	= Pyrotechnic
J	= Joules	Hexachl'b	= Hexachlorobenzene
Fric. P	= Friction	TNC	= tetranitrocarbazole
BR	= Burning rate	PvCl	= Polyvinyl chloride
Ig. Temp	= Ignition temperature	LAM	= Laminac
Compat	= Compatibility	Cel	= Cellulose
Comp	= Composition	Pwd.	= Powder
Uncon	= Unconfined	Ty	= Type
Con	= Confined	Tef	= Teflon
F	= Fiber	P.ester	= Polyester
PA	= Picatinny Arsenal	CaRes	= Calcium resinate
Rec	= Recation	Sps, Spks, Spk	= Sparks
DTA	= Differential thermal analysis	Pb	= Partial burn
Gr	= Group	Propel't	= Propellant
Haz	= Hazard	TFE	= tetraflouroethylene
BM	= Bureau of Mines	Cl	= Class
Exp	= Explodes	Sp	= Specification
Cra, Cr	= Crackles	El	= Ellipsoidal
NR	= No reaction	Opt	= Optimal
St.	= Stearic		
Snps, Snps	= Snaps		
St.	= Starter		
Mod	= Moderate		
B	= Binder		
BOE	= Bureau of Explosives		
Solu	= Solution		
Nc	= Nitrocellulose		
pts	= parts		
Ace	= Acetone		
Tox	= Toxic		
SI-Mod	= Slight to moderate		
ERL	= Energetics Research Laboratory		
Bk.	= Black		
B.Acetate	= Butyl Acetate		
CD	= Complete detonation		
CAR. SUS	= Carcinogen suspect		
MEK	= Methyl Ethyl Ketone		
CB	= Complete burning		
D.earth	= Diatomaceous Earth		
E. Acetate	= Ethyl acetate		

Table 3
Candidate first fire compositions

<u>Constituent</u>	<u>Requirements</u>	<u>Nominal weight percent</u>		
		<u>SM-XXV</u>	<u>IM-6</u>	<u>I-548</u>
Silicon	MIL-S-230 Grade II, Class C	25.7	40.0	---
Potassium nitrate	MIL-P-156 Class I	34.6	54.0	---
Charcoal	JAN-C-178 Class D	4.0	---	--
Aluminum powder	MIL-A-512 Type II, Grade C, Class 4	12.8	---	---
Red iron oxide	MIL-I-275 Grade D	21.7	---	---
Nitrocellulose	MIL-N-244 Grade D	1.2	---	---
Viton A	Commerical	---	6.0	---
Strontium peroxide	MIL-S-612 Grade B	---	---	65.0
Calcium resinate	MIL-C-20470 Type II	---	---	7.0
Calcium resinate	MIL-C-20470 Type I	---	---	13.0
Magnesium powder	MIL-M-382 Type III, Granulation 12	---	---	15.0

Table 4
Static tunnel (ARDEC) data for various illuminant assemblies

<u>Assembly for</u>	<u>First Fire</u>	<u># Assemblies</u>	<u>Burn Time, sec</u>	<u>Average Candlepower</u>	<u>Average Efficiency candle-gram/sec</u>	<u>Average Color Value</u>
M125A1 Green Star	FF-III	10	5.1±0.3	5516±1040	2347±430	0.42±0.02
Cluster Ground	IM-6	10	5.6±0.5	4196±1165	1924±471	0.41±0.01
Illumination Signal	SM-XXV	10	5.4±0.5	5962±991	2677±282	0.41±0.00
M158 Red Star	FF-II	10	4.2±0.4	19349±3696	6811±1257	0.54±0.01
Cluster Ground	IM-6	10	4.8±0.4	21177±2897	8511±1533	0.54±0.01
Illumination Signal	SM-XXV	10	4.6±0.5	20323±1193	7717±717	0.53±0.00
M127A1 White Star	FF-I	10	37.9±1.5	76788±4367	34302±2084	0.05±0.00
Parachute Ground	IM-6	10	39.0±1.2	56962±1734	26275±8204	0.04±0.00
Illumination Signal	SM-XXV	10	38.6±0.8	80780±5359	36784±2806	0.05±0.00
M583A1 White Star	FF-I	10	26.0±2.9	110631±4513	36827±3874	N. A.
40mm Parachute	IM-6	10	21.0±4.6	112867±16744	32251±3358	N. A.
Cartridge	SM-XXV	10	23.2±2.4	106327±11498	32369±2655	N. A.

Table 5
Static tunnel (LHAAP) data for standard and candidate illuminant assemblies

<u>Assembly</u>	<u>First fire</u>	<u>No. assemblies</u>	<u>Average burn time, sec</u>	<u>Average candlepower</u>
M127A1	FF-I	20	34.0 ± 0.8	$114,100 \pm 5,890$
M127A1	SM-XXV	20	31.0 ± 0.9	$135,100 \pm 9,010$

Table 6
Ballistic data for signals conditioned at -65°F

	# Fired	M127 with FF-I	M127 with SM-XXV	Requirements
	# Functioned	16	16	16
		16	16	16
Altitude, feet	Average	715±38	700±76	None
	Maximum	805	784	None
	Minimum	652	433	None
	Average	6.0±3.2	11.0±9.1	≤25
Angle, degrees	Maximum	14	44	None
	Minimum	2	3	None
	Average	0.82±0.08	0.82±0.15	None
Chute Delay, seconds	Maximum	0.92	1.29	5
	Minimum	0.66	0.63	None
	Average	37.0±1.3	37.0±1.2	None
Burn Time, seconds	Maximum	39.1	38.7	None
	Minimum	34.1	35.1	25

Table 7
Ballistic data for signals conditioned at 70°F

	# Fired	M127 with FF-I	M127 with SM-XXV	Requirements
	# Functioned	32	32	32
		32	30	32
Altitude, feet	Average	815±34	821±42	>725
	Maximum	889	916	None
	Minimum	719	743	500
Angle, degrees	Average	4.0±2.4	4.0±2.4	≤12
	Maximum	10	9	30
	Minimum	1	1	None
Chute Delay, seconds	Average	0.72±0.06	0.74±0.09	None
	Maximum	0.91	0.95	5
	Minimum	0.64	0.59	None
Burn Time, seconds	Average	32.9±1.2	32.5±0.8	None
	Maximum	34.7	34.9	None
	Minimum	30.6	30.5	25

Table 8
Ballistic data for signals conditioned at 165°F

	M127 with FF-I	M127 with SM-XXV	Requirements
# Fired	32	32	32
# Functioned	32	32	32
Average	828 \pm 34	845 \pm 25	None
Maximum	886	916	None
Minimum	684	803	None
Average	4.0 \pm 2.5	4.0 \pm 2.4	None
Maximum	10	8	None
Minimum	1	0	None
Average	0.67 \pm 0.08	0.69 \pm 0.10	None
Maximum	0.83	1.06	None
Minimum	0.53	0.56	None
Average	31.2 \pm 1.3	30.6 \pm 1.3	None
Maximum	35.1	33.8	None
Minimum	28.8	28.4	None

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